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Enhancement Of Heat Transfer Using Nano-Fluids

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Abstract:

A colloidal mixture of nano-sized particles in a base fluid, called nanofluids, tremendously enhances the heat transfer characteristics of the original fluid, and is ideally suited for practical applications due to its marvelous characteristics. Nanofluids are colloidal mixtures of nanometric metallic or ceramic particles in a base fluid, such as water, ethylene glycol or oil. Nanofluids possess immense potential to enhance the heat transfer character of the original fluid due to improved thermal transport properties. In this article, a brief overview has been presented to address the unique features of nanofluids, such as their preparation, heat transfer mechanisms, conduction and convection heat transfer enhancement, etc. The hot-wire apparatus is used to measure the thermal conductivity of nanofluids with suspended copper nanophase powders. Some factors such as the volume fraction, dimensions, shapes and properties of the nanoparticles are discussed. A theoretical model is proposed to describe heat transfer performance of the nanofluid flowing in a tube, with accounting for dispersion of solid particles.

Keywords — ***Nanofluid, Enhanced heat transfer, the hot-wire apparatus, Dispersion.***

INTRODUCTION

Nanofluids have moved closer to engineering reality since their conception more than a decade ago. Because of the increased interest in practical applications of nanofluids in the last ten years, more attention has been paid to improving the convective heat transfer performance of nanofluids [1]. Heat exchangers are widely used in a variety of engineering applications, including power generation, chemical manufacturing, food processing, environmental engineering, waste heat recovery, air conditioning, and refrigeration. Efforts have been made for decades to improve heat transfer in heat exchangers, reduce heat transfer time, and ultimately improve energy utilisation efficiency. These efforts frequently include both passive and active methods, such as creating turbulence, extending the exchange surface, or using a fluid with better thermophysical properties. [2]

Heat transfer enhancement techniques can improve the performance of industrial and practical appliances to perform some important heat transfer duties. Nanofluid heat transfer enhancement has been used as one of the passive heat transfer techniques in a variety of heat transfer applications. It is thought to have a high potential for heat transfer enhancement and is well suited for use in heat transfer processes. Several significant research projects have been completed in recent years to understand and explain the causes of heat transfer enhancement or control using nanofluids. This review focuses on the unique properties of nanofluids, such as improved heat transfer, increased thermal conductivity, increased surface volume ratio, Browanian motion, and so on. [3]

NANOFLUIDS

Nanofluids are solid-liquid composite materials made up of solid nanoparticles or nanofibers with sizes ranging from 1 to 100 nm that are suspended in liquid. Even a small amount (1% volume fraction) of Cu nanoparticles or carbon nanotubes dispersed in ethylene glycol or oil has been shown to increase the liquid's inherently poor thermal conductivity by 40% and 150%, respectively. To achieve such enhancement, conventional particle-liquid suspensions require high particle concentrations (>10%). However, rheology and stability issues are exacerbated at high concentrations, preventing conventional slurries from being widely used as heat transfer fluids. In some cases, the observed increase in thermal conductivity of nanofluids exceeds the predictions of well-established theories by orders of magnitude. Other puzzling findings in this rapidly evolving field include a surprisingly strong temperature dependence of thermal conductivity and a three-fold higher critical heat flux when compared to base fluids. [4]

COOLING EFFICIENCY OF NANOFLUIDS

The increased thermal conductivity of nanoparticle suspensions was the initial promise of nanofluids as advanced heat transfer fluids. When solid particles are added to conventional fluids, their low thermal conductivity improves. However, the magnitudes of the effects reported in the literature range from a few percent (as predicted by effective medium theory (EMT)) to hundreds of percents (i.e., abnormal enhancements). [5]

Unfortunately, it is not always recognised that thermal conductivity is not the only property that influences heat transfer efficiency in a system. Coolant is pumped through the pipes of a heat exchanger in forced flow systems, introducing convective heat transfer mechanisms and pumping power penalties. The efficiency of various liquid coolants is determined by fluid properties and flow mode (laminar or turbulent)

THE THERMAL PROPERTIES OF NANOFLUIDS

The thermal properties of nanofluids have gotten a lot of attention. Nanofluids are thought to have significant advantages over conventional heat transfer fluids. A number of experimental studies on the transport properties of nanofluids have been conducted, including:[6]

$$\rho_{nf} = \left(\frac{\phi}{100}\right)\rho_p + \left(1 - \frac{\phi}{100}\right)\rho_f$$

$$C_{nf} = \frac{\frac{\phi}{100}(\rho C)_p + \left(1 - \frac{\phi}{100}\right)(\rho C)_f}{\rho_{nf}}$$

Heat capacity of nanofluids

By assuming thermal equilibrium between the nanoparticles and the base fluid phase, the specific heat of nanofluid can be calculated as follows:

$$\begin{aligned}(\rho c)_{eff} &= \rho_{eff}\left(\frac{Q}{m\Delta T}\right)_{eff} = \rho_{eff}\frac{Q_f + Q_p}{(m_f + m_p)\Delta T} \\ &= \frac{(mc)_f\Delta T + (mc)_p\Delta T}{(m_f + m_p)\Delta T} \rightarrow (\rho c)_{eff} \\ &= \rho_{eff}\frac{(\rho c)_f V_f + (\rho c)_p V_p}{\rho_f V_f + \rho_p V_p} \Rightarrow c_{eff} = \frac{(1-\phi_p)\rho_f c_f + \phi_p \rho_p c_p}{\rho_{eff}}\end{aligned}$$

where q_p is the nanoparticle density, q_f is the base fluid density, q_{eff} is the nanofluid density, and cp and c_f are the heat capacities of the nanoparticle and the base fluid, respectively.

REVIEW OF LITERATURE

Xuan and Roetzel [7] proposed a two-phase thermal dispersion model in which it is assumed that the convective heat transfer enhancement in nanofluids results from two factors: I higher thermal conductivity, and (ii) nanoparticle thermal dispersion. The effect of the nanoparticle/base fluid relative velocity and temperature is treated as a perturbation of the energy equation in this approach. To describe the heat transfer enhancement, the thermal dispersion coefficient is introduced.

Khanafer et al. [8] investigated heat transfer enhancement in a two-dimensional enclosure using nanofluid. The effective thermal conductivity was calculated as the sum of the conventional theory thermal conductivity and a dispersion thermal conductivity. The effect of temperature on thermal conductivity is not taken into account in many numerical studies of convection. However, das et al. [41] demonstrated that temperature has a significant effect on the thermal conductivity of nanofluid.

Kim et al. [9] investigated the thermo-diffusion and diffusion thermo effects on convective instabilities in binary nanofluids theoretically. This study uses data from silver and copper nanofluid studies to show that the particles cause a unique convective motion in binary nanofluids. The Socet effect improves heat transfer in binary nanofluids more than it does in mono-nanofluids. Furthermore, due to silver's higher thermal conductivity, the heat transfer coefficient of silver nanofluids is greater than that of copper. According to studies, the Soret and Dufour diffusions make nanofluids unstable, and this is more pronounced for denser nanofluids. Furthermore, as concentration increases, convective motion in nanofluids easily sets in both effects.

Chang et al. [10] conducted natural convection experiments in enclosures using Al2O3microparticle (!250 nm) aqueous suspensions. Their findings appear to indicate that the particles have no effect on the Nusselt number values in a vertical enclosure. However, at lower Rayleigh numbers and higher particle concentrations, there was a decrease in Nusselt number compared to the presence of pure water in the horizontal enclosure. This unusual behaviour was attributed to sedimentation by the authors.

Ho et al. [11] investigated natural convection heat transfer of a nanofluid in a vertical enclosure for various particle sizes and volume fractions of nanoparticles (Al2O3) ranging from 0.1% to 4%, as well as Rayleigh number variations ranging from 105-108. Over the entire range of Rayleigh numbers, they observed systematic heat transfer degradation in nanofluids containing nanoparticles with volume fractions greater than 2%. However, heat transfer enhancement of around 18% was observed for nanofluid containing lower nanoparticle concentrations of 0.1% at high Rayleigh number.

Khanafer et al. [12] investigated natural convection heat transfer of nanofluids in an enclosure under various physical constraints. Their findings demonstrated that the average Nusselt number increases as the particle volume fraction increases for different Grash of number.

OBJECTIVE

- To study the effects of particle volume fraction on the thermal conductivity
- To study relation between temperature and viscosity
- To study clustering phenomenon
- To study multivariable of a nanofluid system

RESEARCH METHODOLOGY

Methodology is the systematic, theoretical examination of the methods used in a particular field of study. It consists of a theoretical examination of the body of methods and principles associated with a particular field of knowledge. It usually includes terms like paradigm, theoretical model, phases, and quantitative or qualitative techniques. The current study is descriptive in nature and is based on secondary data gathered from a variety of sources such as books, education, and development, journals, scholarly articles, government publications, and printed and online reference materials.

RESULT AND DISCUSSION

The correlations between nanofluid engineering parameters and nanofluid properties are depicted schematically in Fig 1[13].

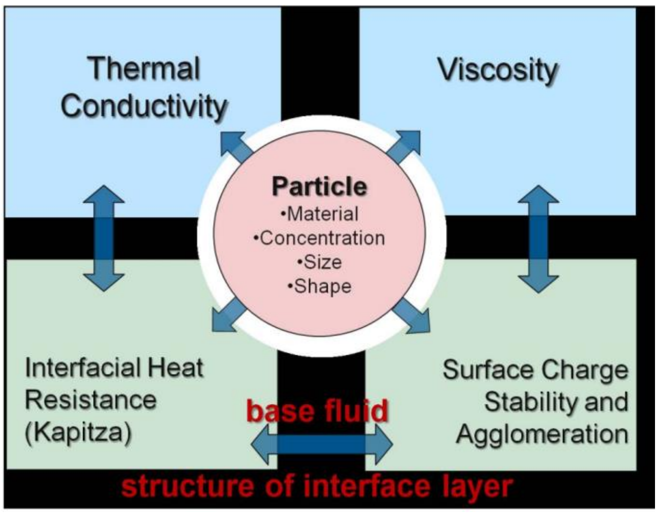

Fig. 1: Schematic representation of the multivariability of a nanofluid system.

Clusters of nanoparticles have been observed. Fractal theory can be used to deal with these clusters. Evans et al. proposed that clustering can result in fast heat transport over relatively long distances because heat is conducted much faster by solid particles than by liquid matrix. This phenomenon is depicted schematically below. [14]

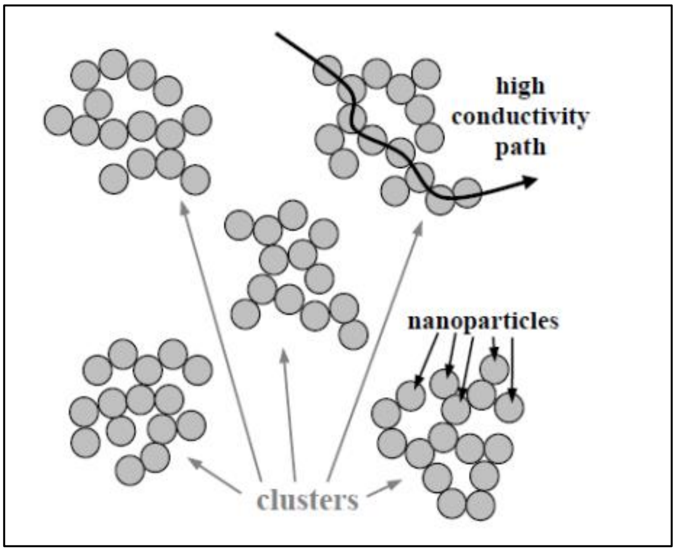

Figure 2: A schematic representation of the clustering phenomenon. A high conductivity path allows for rapid heat transport over long distances.

It was discovered that the effective thermal conductivity increased with cluster size. However, as the particle volume fraction increased, the thermal conductivity enhancement of the nanofluid with clusters decreased. [15-17]

There are two lines: one for base fluid without nano particles and another for ice dragon fluid, a type of nano fluid. The figure shows that as we raise the temperature of the nano fluid, the viscosity decreases. However, the viscosity of the nano fluid decreases significantly when compared to the base fluid. [18-19]

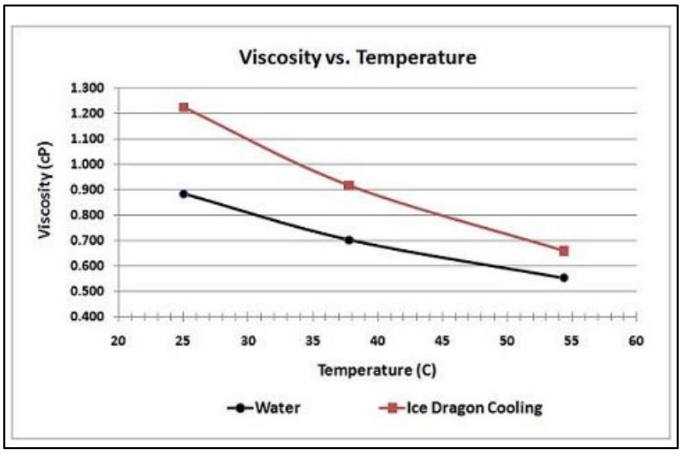

Fig. 3: Plot between Temperature and Viscosity

Figure 4,5 depicts the effects of particle volume fraction on the thermal conductivity of nanofluids. The effects of particle volume fraction on thermal conductivity for transformer oil-copper nanofluid and water-copper nanofluid are shown in Figs. 4 and 5, respectively. [20]

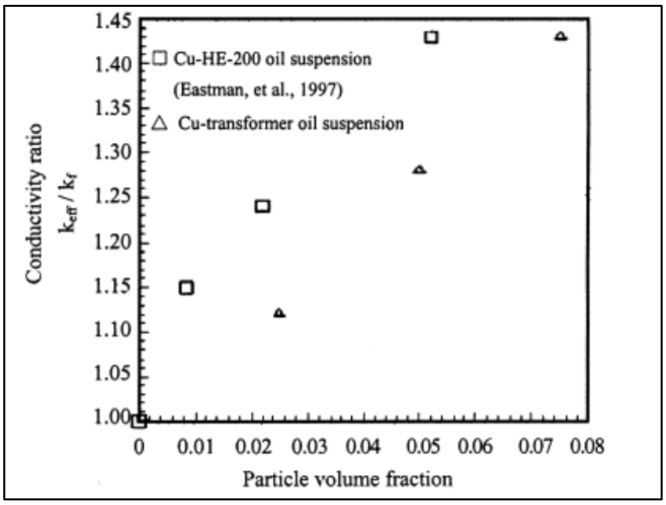

Fig. 4 The effects of particle volume fraction on the thermal conductivity for the transformer oil–copper nanofluid.

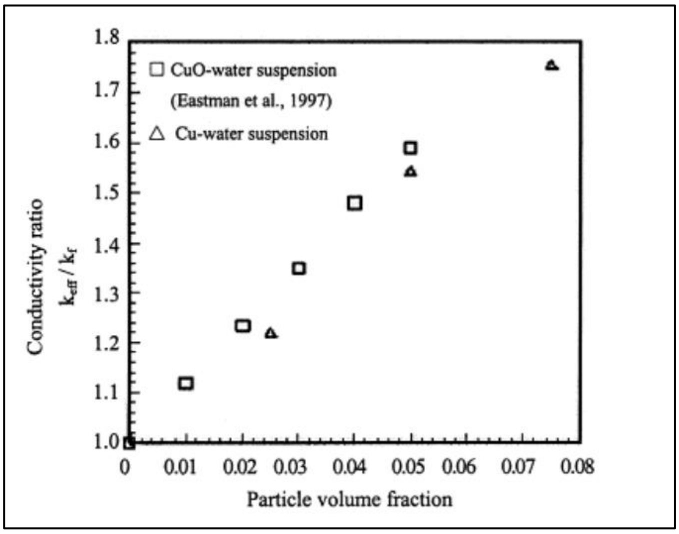

Fig. 5: Effects of particle volume fraction on thermal conductivity of water-copper nanofluid.

CONCLUSION

This demonstrates that nanofluids have a high potential for heat transfer enhancement and are well suited for use in heat transfer processes. Nanofluids are a new type of heat transfer fluid created by dispersing metallic or non-metallic nanoparticles smaller than 100 nm in a liquid. Understanding the fundamentals of heat transfer and wall friction is critical for developing nanofluids for a variety of heat transfer applications. Thermal conductivity of nanofluids increases with particle volume fraction and temperature. The chaotic movement of nano particles increases fluid fluctuation and turbulence, which speeds up the heat exchange process. Increasing the particle concentration and the Reynolds number improves the convective heat transfer coefficient. Nanofluid side effects such as nanoparticle clustering and coagulation should be avoided.

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